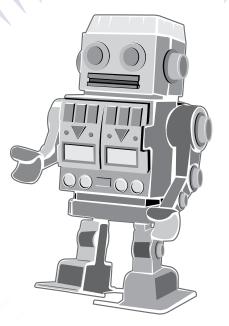
ROBOTIC TOYS AS A CATALYST FOR MATHEMATICAL PROBLEM SOLVING





KATE HIGHFIELD

describes a series
of tasks in which
robotic toys are
used to develop
young children's
mathematical and
metacognitive skills.

Robotic toys present unique opportunities for teachers of young children to integrate mathematics learning with engaging problem-solving tasks. This article describes a series of tasks using Bee-bots and Pro-bots, developed as part a larger project examining young children's use of robotic toys as tools in developing mathematical and metacognitive skills. The tasks provided motivating contexts to promote meaningful learning and engaged children in multiple mathematical processes.

several decades research informed us that young children are capable of accessing powerful mathematics ideas (Perry & Dockett, 2008). The challenge for early childhood professionals, often limited by the crowded curriculum, is to involve all children in engaging activities commensurate with their abilities, and rich tasks that promote mathematics learning. Problem solving tasks enable children to explore multiple mathematical concepts in one context (Lowrie & Logan, 2006). Utilising a multifaceted problem solving approach in this project allowed the children simultaneously and successively to explore measurement, space and geometry, position and estimation through problem solving and reflection. The toys served as catalysts, providing unique opportunities for tasks focussing on dynamic movement. The development of tasks that have multiple solutions engenders flexible thinking and encourages reflective processes. Furthermore, the nature of the toys promotes playful and sustained engagement with challenging mathematical concepts.

Robotic toys

There are many simple robotic toys available: the RoamerToo (Figure 1), Bee-bot (Figure 2), Pro-bot (Figure 3) and Lego NXT. In this project, the Bee-bot and Pro-bot, were chosen by the teachers due to their simple, robust interface. The use of modern robotic toys can be linked to the work of Logo, popular in the 1980s and 1990s, where children programmed a turtle to move around a computer screen. Similarly a floor robot is a real life turtle that can be programmed to move around the floor. As with Logo, the simple robotic toys assist students "externalise intuitive expectations" (Papert, 1980, p. 145). As children program the robot and then observe its movement they can "see" their program in action and decide if their plan has worked as expected. This visual process encourages children to reflect on their program thus making mathematical concepts "more accessible to reflection" (Papert, 1980, p. 145). To program the toys the children use a series of directional buttons and a simple user interface that is accessible to children (for further details of programming see Highfield & Mulligan, 2009).

The robotic tasks project*

Thirty-three children participated in the project, of whom 11 were children, aged three and four years, and drawn from a metropolitan pre-school. Twenty-two Year 1 children from a nearby state school were also involved. None of the children or teachers had experience with robotic toys before they began the project. In both settings the children and their teachers chose to use the Bee-bots and Pro-bots, although a range of robotic toys were supplied. The children were engaged in "play" experiences with the toys and then completed weekly tasks, developed collaboratively by the teachers and the researcher, for approximately 2 hours per week over 12 weeks.

Development and implementation of robotic tasks

Each of the tasks provided opportunities for children to program and observe the robotic toy and to reflect on the toy's movement. The dynamic actions of the toy created a "shared moment" which was highly visual and in turn provided opportunities for shared attention and group work. There were three different types of tasks: structured tasks (teacher-directed tasks designed to develop particular concept or skills); exploratory tasks (structured to allow application of knowledge, exploring concepts and skills more freely); and extended tasks (open-



Figure 1. Roomer Too (Valiant technology).



Figure 2. A Bee-bot (TTS Group).



Figure 3. A Pro-bot (TTS Group).

ended and child-directed tasks with which children engaged for an extended period of time, and with limited teacher scaffolding). Exploratory and extended tasks provide opportunities for problem solving, whereas structured tasks focussed on discrete skills required in the more advanced tasks. Table 1 provides examples of the tasks in the pre-school and Table 2 provides examples from the Year 1 classroom.

In both tables, the tasks are sequenced to suggest a possible learning framework that supports the development of mathematical processes of increasing complexity. The order and difficulty of the tasks can be altered to differentiate teaching for individuals and learning contexts. Exploratory and extended tasks promoted persistence and sustained engagement as the children attempted to complete the problem solving goals.

Table 1. Tasks in the pre-school context.

Task Descriptor

1.Robot play and investigation



An exploratory task: Free play with the robots, with children working individually and in pairs to develop understanding of the symbols used in programming; programming the robot to move between partners to develop measurement concepts; changing the distance increased task difficulty.

2.Building a robot home



An exploratory task: Using plastic blocks to construct an appropriately sized home for the Pro-bot. This developed 2D and 3D spatial sense and measurement skills.

3.Positional language



A structured task: Moving the robot to a finishing point (for example: "move from here to under that chair") to develop positional language; altering the length and complexity of the instructions increases task difficulty.

4.Robots on the ramp



An extended task: Using the outside play equipment, children programmed the robot to move up and down a series of ramps, investigating ramp steepness. This task integrated mathematical and scientific reasoning.

5.Constructing and representing tracks



Exploratory tasks: Using pre-cut lengths of wooden track to make a series of tracks and programming the toy to move around the track using a variety of tools such as directional image cards.

Children represented their planning and execution with invented symbols. Simple square tracks required the use of repeated steps of equal Pro-bot length. This focused on the use of a simple repetitive pattern.

By altering the track complexity the task was made more challenging. Using tracks with irregular angles emphasised the importance of transformation skills.

Table 2. Tasks in the Year 1 context.

Task Descriptor

1.Comparative steps



A structured task: Starting from a base line, the children predicted and compared the step lengths of the two robots. This informed the children's understanding of the robot step as a unit of measure.

2.Partitioning and doubling distance



A structured task: Using a start, finish and half way point (with masking tape) children estimated and programmed the robot to move to the half way point and then doubled the number of steps to complete the task. This enabled the children to partition and iterate distance as equal-sized units and apply number sense by doubling.

3. Robot people



A structured task: Using the language of robotic programming (forward, reverse and rotations) to "program" a peer to move around a room, or around a large grid. This enabled spatial concepts including viewing from different orientations and perspectives.

4.Robot speedway



An exploratory task: Setting out a number of small cones (or cups) and programming the toy to weave between the cones. Adding cones simplified the process, as did placing the cones on a grid pre-marked to scaffold the robot's step.

5.Moveable island



An extended task: Creating a teacher-made island on a grid (pre-marked with the robots step length). By adding a series of obstacles (e.g., a tree, bridge, waterfall, quick-sand) that could be moved children were able to "create" an adventure for their toy; for example: "Go under the bridge to the waterfall, don't touch the quicksand". Extended engagement is afforded and complexity of task increased as children place obstacles and prescribe routes in a variety of ways.

6.Design your own island



An extended task: Children, working in small groups, designed and made an island for their toy, using recycled two and three dimensional materials to create obstacles. Children then programmed the robot to move through their island.

A combination of structured and exploratory tasks allowed students to develop and apply skills in programming and controlling the robotic toys. Extended tasks provided opportunities for students to attend to multiple mathematical focuses simultaneously. In the pre-school context the

flexible timetable afforded children time to complete tasks at their own pace. Moreover the pre-school aged children had freedom represent their thinking in their own way. The children were able to investigate without the limitations of a prescriptive curriculum. In the school context the teacher endeavoured to provide opportunities for sustained investigation but this was made difficult by imposed school structures such as class size and timetabling. More formalised expectation of the task completion and representation may also have limited the potential for independent investigation in this context.

cognitive **Mathematics** and processes

Table 3 provides examples of how the toy and the task combine to promote various mathematical concepts and processes.

| Table 3. Processes and concepts explored while using simple robotic toys. | |
|---|---|
| Spatial concepts | Capacity: Creating and measuring space that is large enough for the toy to move through (such as a tunnel) or fit inside (such as a garage). Angle of rotation: Exploring the rotation of the toy as a pre-set 90° angle, creating pathways that utilise a 90° angle. Directionality: Examining concepts such as forward, backward, rotate, left, right and positional language. Position on a plane: Using increasingly complex language, "over there" becomes "in the far left corner". Using terms such as over, under, beside, through, near and far. Transformational geometry: Exploring concepts such as rotation and linear motion. |
| Measurement | Informal and formal units: Using informal units, such as hands, counters, blocks, or the toy's length, and formal units such as measuring tapes to ascertain distances and assist in creating programs. Identification and Iteration of a unit of measure: Using the toy's pre-set step as a unit of measure, when moving the toy; using hand and eye gestures as place holders in measuring distance. Direct comparison: Using the toy's length to compare directly the distances needed to complete a pathway. |
| Structure | Grid: Developing and using grids showing the toy's step length to assist in planning and developing programs Gesture and movement: Using gestures and body movement to indicate and imagine the structure of regular steps, For example, when asked how she knew what the program required, a child responded "I imagined where the steps would be". |
| Number | Perceptual and figurative counting: Engaging in both perceptual and figurative counting to ascertain the number of steps required to complete a given pathway. Comparison of number: When comparing programs or movement pathways the children frequently compared number; for example: "I went eight forward and you only went six forward and so mine went further". |
| Problem Solving | Estimation: Predicting and estimating the number of steps required to complete a pathway; examining the estimation to assess reasonableness before programming. Re ecting: Observing a program, re ecting on attempts, and making the changes required Trial and error: developing Confidence to trial a program, even if incorrect and identifying errors. Recall of prior knowledge: recalling prior knowledge and skills to apply in programs. Investigating multiple solutions: Predicting and developing multiple solutions to tasks; for example, travelling clockwise, or anti-clockwise. Evaluating solutions: Examining the efficiency of a program to decide if it was most effective. |
| Representation | Semiotic understanding of symbols: In order to program the robot to move the children needed to develop an understanding of what each symbol meant. The forward arrow meaning one step forward, arrows to the left or right meaning rotation (not movement to the right). Constructing and recording programs using symbols: After completing a program the children represented what they had done in the "robot diaries". This required learners to develop a symbol system representing their program. Symbols include talling arrows and |

develop a symbol system representing their program. Symbols include tallies, arrows and

invented notations to show movement and location.

Implications for teaching and learning

In both contexts the problem solving tasks demonstrated potential for teaching and learning with a programmable toy. However, it is not known whether the outcomes of this project can be generalised to other pedagogical contexts, as the project was limited to a small cohorts of children, whose teachers were supported by the researcher and provided with the resources. In this project it is significant that the children engaged in multiple mathematical processes concurrently and sequentially; and they demonstrated perseverance, motivation and responsiveness to these tasks that would not usually be evident in their regular programs. It is reasonable to expect that the combination of robotic toys and engaging tasks would promote similar results in other classroom contexts.

This project suggests that a multifaceted approach, integrating and inter-relating concepts, processes and skills through dynamic tasks can promote rich mathematical thinking and sustained engagement. Research in this area is ongoing and it is hoped that future work, including micro-analysis of children's mathematical problem solving and metacognitive processes, will inform pedagogy and practice for young learners.

Note

This project forms part of the author's current PhD research at Macquarie University.

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